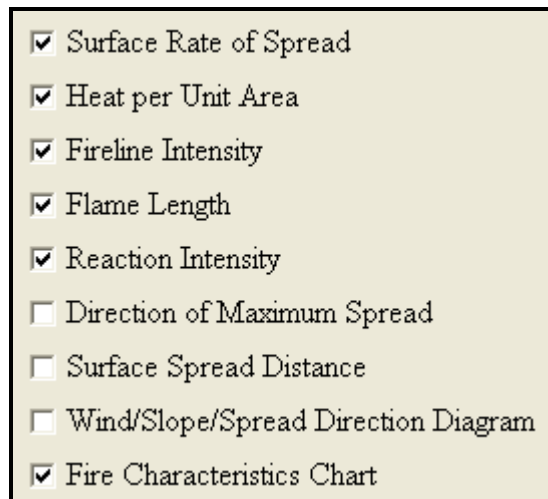


Exercise Answers

The following exercises will explore aspen outputs using each of the five fuel models. The exercises will also explore parameters necessary to limit (or enhance) aspen mortality. Prescriptions may range from maintaining aspen cover to removing an aspen overstory to enhance suckering. According to Brown and Simmerman (1986) fires having Flame Lengths greater than 1.7 to 2.1 feet will kill aspen trees. But, Flame Lengths of 1 to 1.5 feet are needed to sustain fire spread. Finding the balance between conditions adequate to sustain burning and maintaining adequate control and reaching mortality objectives can be challenging in this fuel type. Some inputs will follow information given in Brown and Simmerman (1986).

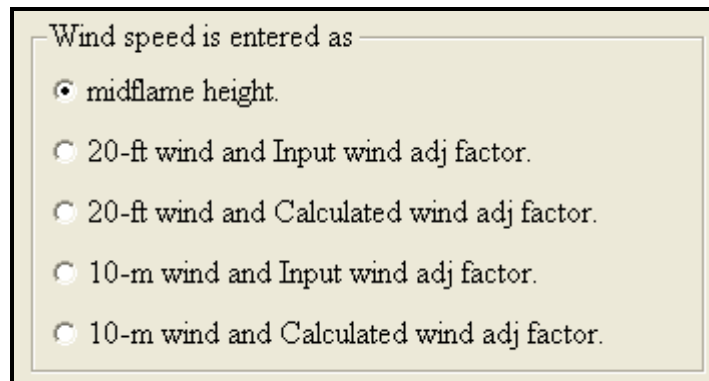
1. In the lesson example, our fuel inputs lead to very high aspen mortality. Use the following inputs to explore the effect of aspen D.B.H on mortality.

- Use the **Aspen/shrub** model.
 - **Aspen Curing Level** ranges from “0” to “90” by “30”% steps.
 - **D.B.H.** ranges from “10” to “40” by “10” inch increments.
 - **Fuel moistures** are “8” for 1-h, “10” for 10-h.
 - Typically, live fuel moisture would decrease with increased curing. To simplify the entry, use “150” for live herbaceous and “85” for live woody moisture.
 - **Midflame Wind Speed** is “5” mi/h.
 - **Slope** is “0”%.
 - **Aspen fire severity** is “Low.”
-
- Open the **BasicStart.bpw** Worksheet.
 - Enter “Western Aspen Exercise 1 – Aspen/Shrub Low Severity” in the **Description** window of the Worksheet.
 - Click **Module Selection > SURFACE > Options...**
 - On the **Basic Outputs** tab, select Surface Rate of Spread, Heat per Unit Area, Fireline Intensity, Flame Length, Reaction Intensity, and Fire Characteristics Chart.



- ☒ Surface Rate of Spread
- ☒ Heat per Unit Area
- ☒ Fireline Intensity
- ☒ Flame Length
- ☒ Reaction Intensity
- ☐ Direction of Maximum Spread
- ☐ Surface Spread Distance
- ☐ Wind/Slope/Spread Direction Diagram
- ☒ Fire Characteristics Chart

- On the **Wind Speed** tab, make sure that **Wind speed is entered as midflame height** is selected.



Wind speed is entered as —

- ☒ midflame height.
- ☐ 20-ft wind and Input wind adj factor.
- ☐ 20-ft wind and Calculated wind adj factor.
- ☐ 10-m wind and Input wind adj factor.
- ☐ 10-m wind and Calculated wind adj factor.

- On the **Fuel & Moisture** tab, click on **Fuel is entered as Special case fuel model, western aspen (Brown and Simmerman 1986)**.

Fuel is entered as —

- ☐ Fuel models (standard or custom).
- ☐ Fuel parameters (for custom fuel modeling).
- ☐ Two fuel models,
2-dimensional expected spread (recommended).
- ☐ Two fuel models,
harmonic mean.
- ☐ Two fuel models,
area weighted (like old BEHAVE).
- ☐ Special case fuel model,
palmetto-gallberry (Hough and Albini 1978).
- ☒ Special case fuel model,
western aspen (Brown and Simmerman 1986).

Dynamic curing load transfer is —

- ☒ calculated from live herbaceous
fuel moisture.
- ☐ input directly.

Moisture is entered by —

- ☒ individual size class.
- ☐ dead and live category.
- ☐ moisture scenario.

Remember, inputs to the **Dynamic curing load transfer** are ignored in this model. This model uses the level of curing to calculate load transfers.

Calculations of fuel loads, surface-area-to-volume ratios, and mortality outputs for the western aspen model are initiated by checking the appropriate boxes through the Aspen Outputs screen.

- On the **Aspen Outputs** tab, click on 1-h Fuel Load and Probability of Aspen Mortality.

Calculated for Aspen special case fuel models:

☒ 1-h Fuel Load

☐ Live Herbaceous Fuel Load

☐ Live Woody Fuel Load

☐ 1-h SA/V

☐ Live Woody SA/V

☒ Probability of Aspen Mortality

NOTE: Remember to select 'Special case fuel model, western aspen' on the 'Fuel & Moisture' tab.

➤ Click **Ok** twice.


Fill in the inputs as follows:

- Aspen Fuel Model = Aspen/shrub (select using the Guide ➡ button).
- Aspen Curing Level = 0 to 90 by 30% increments.
- D.B.H. = 10 to 40 by 10-inch increments.
- Fuel moisture:
 - 1-h Fuel Moisture = 8%
 - 10-h Fuel Moisture = 10%.
- Typically, live fuel moisture would decrease with increased curing. To simplify the entry, use
 - Live Herbaceous Moisture = 150, and
 - Live Woody Moisture = 85.
- Midflame Wind Speed = 5 mi/h.
- Slope = 0%.
- Aspen Fire Severity = Low (select using the Guide ➡ button).
- Add the following statement to **Notes**: “Aspen/shrub model, range of curing, range of DBH, low severity”


Your two-page Worksheet should now look like the following.


BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 1

Inputs: SURFACE


Description  Western Aspen Exercise 1 - Aspen/Shrub Low Severity

Fuel/Vegetation, Surface/Understory


Aspen Fuel Model  Aspen/shrub


Aspen Curing Level %  0, 30, 60, 90


Fuel/Vegetation, Overstory


D.B.H. in  10, 20, 30, 40


Fuel Moisture

1-h Moisture %  8


10-h Moisture %  10

100-h Moisture %  150


Live Herbaceous Moisture %  150

Live Woody Moisture %  85


Weather

Midflame Wind Speed (upslope) mi/h  5

Terrain

Slope Steepness %  0

Fire

Aspen Fire Severity  Low

Run Option Notes

A special case fuel model is used: western aspen (Brown and Simmerman 1986) [SURFACE].

Maximum reliable effective wind speed limit is NOT imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]

Heat per Unit Area (Btu/ft²) [SURFACE]

Fireline Intensity (Btu/ft/s) [SURFACE]

Flame Length (ft) [SURFACE]

Reaction Intensity (Btu/ft²/min) [SURFACE]

(continued on next page)

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 2

Input Worksheet (continued)


Fire Characteristics Chart [SURFACE]

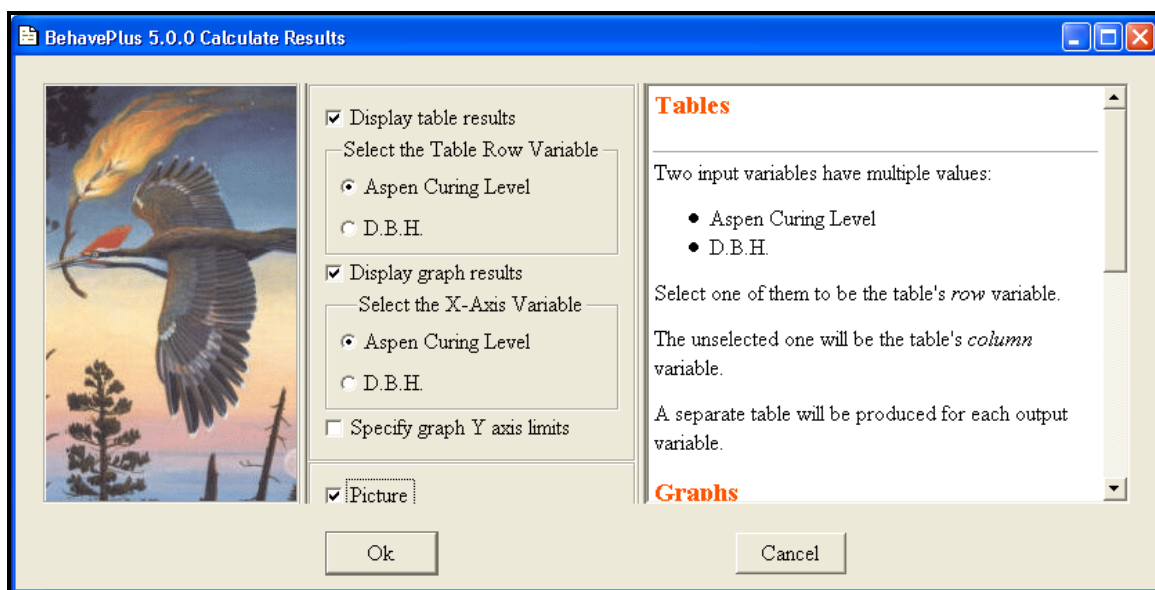
1-h Fuel Load (ton/ac) [SURFACE]

Probability of Aspen Mortality (%) [SURFACE]

Notes

Aspen/shrub model, range of curing, range of DBH, low severity

- Click the **Calculate** button ().
- Choose to display both table results and graph results using Aspen Curing Level as the table row and X-Axis Variable. The screen capture below also shows the Help screen associated with these choices.



➤ Click **Ok**.

The outputs follow. As you review the fire behavior output tables, note that D.B.H. has no influence on surface fire behavior. Curing Level does influence fire behavior outputs.

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 3

Western Aspen Exercise 1 - Aspen/Shrub Low Severity
Surface Rate of Spread (maximum) (ch/h)

Curing Level	D.B.H. in			
%	10	20	30	40
0	6.3	6.3	6.3	6.3
30	7.3	7.3	7.3	7.3
60	10.6	10.6	10.6	10.6
90	15.8	15.8	15.8	15.8

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 4

Western Aspen Exercise 1 - Aspen/Shrub Low Severity
Heat per Unit Area (Btu/ft²)

Curing Level	D.B.H. in			
%	10	20	30	40
0	359	359	359	359
30	371	371	371	371
60	401	401	401	401
90	429	429	429	429

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 5

Western Aspen Exercise 1 - Aspen/Shrub Low Severity
Fireline Intensity (Btu/ft/s)

Curing Level %	D.B.H. in			
	10	20	30	40
0	41	41	41	41
30	50	50	50	50
60	78	78	78	78
90	124	124	124	124

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 6

Western Aspen Exercise 1 - Aspen/Shrub Low Severity
Flame Length (ft)

Curing Level %	D.B.H. in			
	10	20	30	40
0	2.5	2.5	2.5	2.5
30	2.7	2.7	2.7	2.7
60	3.3	3.3	3.3	3.3
90	4.1	4.1	4.1	4.1

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 7

Western Aspen Exercise 1 - Aspen/Shrub Low Severity
Reaction Intensity (Btu/ft²/min)

Curing Level %	D.B.H. in			
	10	20	30	40
0	1971	1971	1971	1971
30	1997	1997	1997	1997
60	2157	2157	2157	2157
90	2350	2350	2350	2350

The 1-h Fuel Load (Page 8 of the Run) does not change with changes in D.B.H., but it does change with Curing Level as seen in the lesson and this exercise. This pattern follows through all aspen fuel load and surface-area-to-volume ratio outputs. You can verify this by running the model again with the additional aspen outputs.

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 8

Western Aspen Exercise 1 - Aspen/Shrub Low Severity
1-h Fuel Load (ton/ac)

Curing Level %	D.B.H. in			
	10	20	30	40
0	0.800	0.800	0.800	0.800
30	0.893	0.893	0.893	0.893
60	1.137	1.137	1.137	1.137
90	1.379	1.379	1.379	1.379

On Page 9 of the BehavePlus Run is the table of Probability of Aspen Mortality.


BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:37:00 Page 9

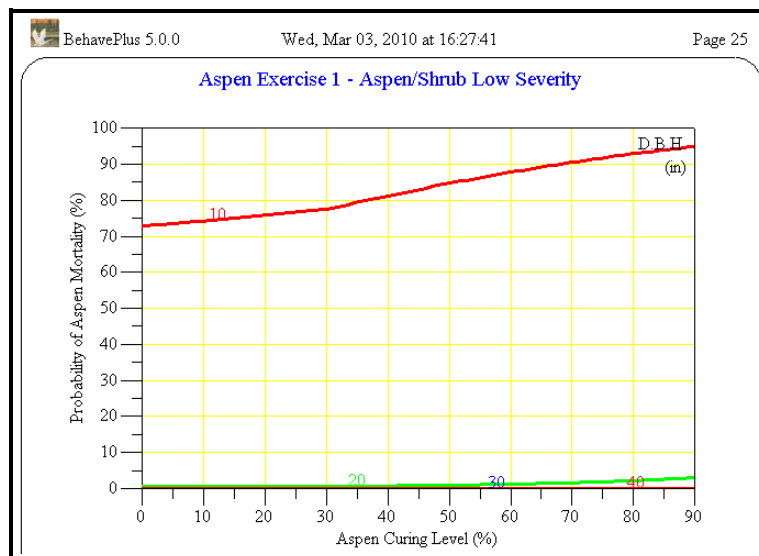
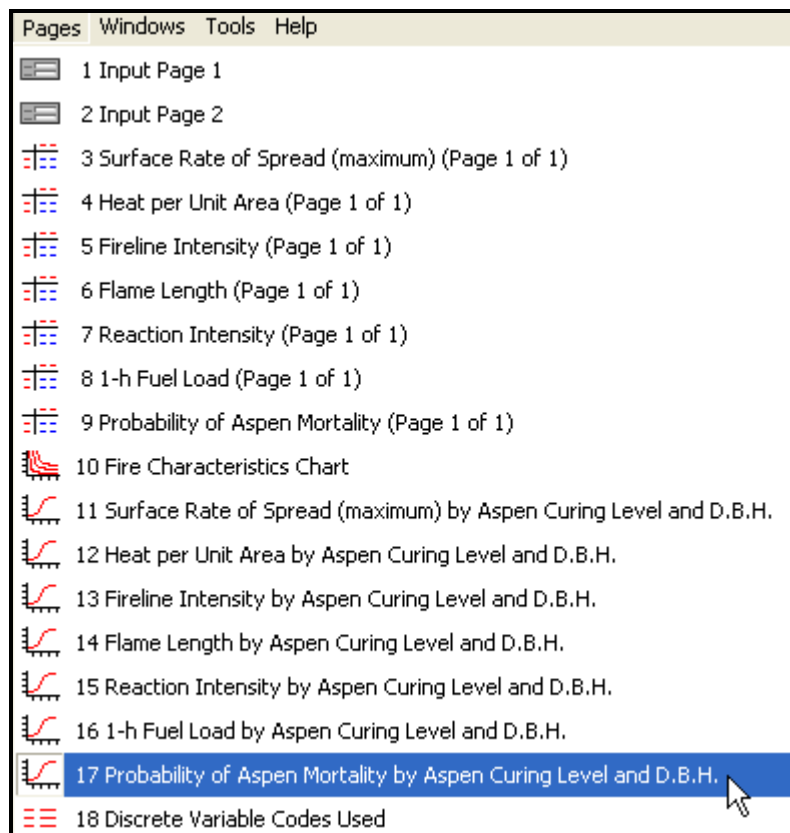
Western Aspen Exercise 1 - Aspen/Shrub Low Severity
Probability of Aspen Mortality (%)

Curing Level %	D.B.H. in			
	10	20	30	40
0	73	0	0	0
30	78	1	0	0
60	88	1	0	0
90	95	3	0	0

There is a distinct survival advantage to aspen with larger D.B.H. under these relatively dry conditions.

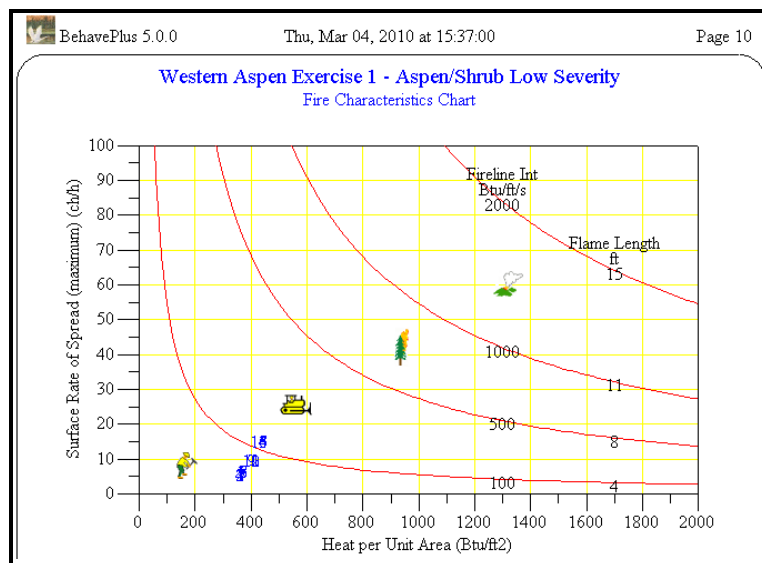
Skip ahead to page 17 to view the graph of Probability of Aspen Mortality as a function of Aspen Curing Level.

You can use the  toolbar button to advance page by page through the results, or, use **Pages** on the menu bar to go directly to the page of interest.




The graph of mortality and curing shows the distinct survival advantage of trees with a larger D.B.H.

Return to page 10 to view the Fire Characteristics Chart using the **Pages** menu bar selection.



The Runs cluster at the lower left of the Fire Characteristics Chart, indicating relatively low to moderate fire behavior.

2. Explore mortality through the other aspen fuel models using the same inputs as in Exercise 1, changing only the Aspen Fuel Model until all four remaining aspen models are examined.

Continuing from Exercise 1, return to the first Worksheet page by clicking the  toolbar button.

- Change the **Description** line of the **Input** portion of the Worksheet to create appropriate identifying titles for the tables and graphs.
- Change the Aspen Fuel Model to Aspen/tall-forb.

All other inputs remain the same.

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 15:47:47 Page 1

Inputs: SURFACE

Description ➤ Western Aspen Exercise 2 - Aspen/Tall-Forb, Low Severit

Fuel/Vegetation, Surface/Understory

Aspen Fuel Model ➤ Aspen/tall-forb

Aspen Curing Level % ➤ 0, 30, 60, 90

Fuel/Vegetation, Overstory

D.B.H. in ➤ 10, 20, 30, 40

Fuel Moisture

1-h Moisture % ➤ 8

10-h Moisture % ➤ 10

100-h Moisture % ➤ 150

Live Herbaceous Moisture % ➤ 150

Live Woody Moisture % ➤ 85

Weather

Midflame Wind Speed (upslope) mi/h ➤ 5

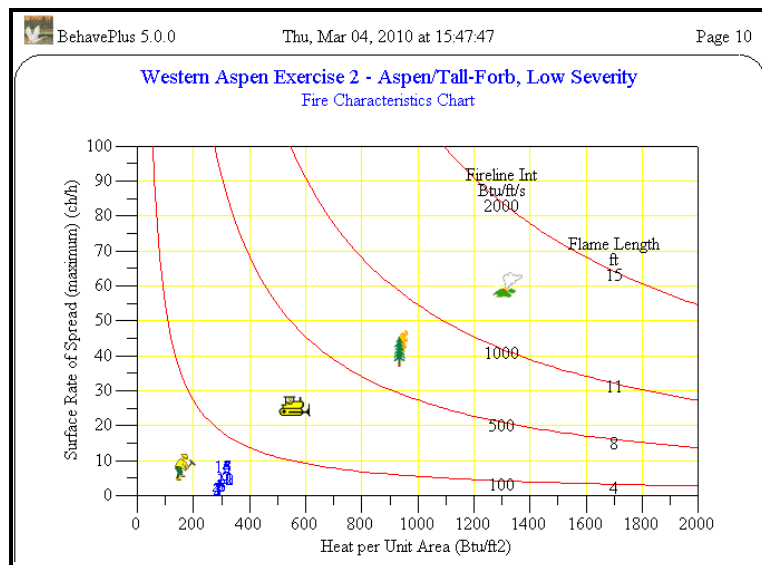
Terrain

Slope Steepness % ➤ 0

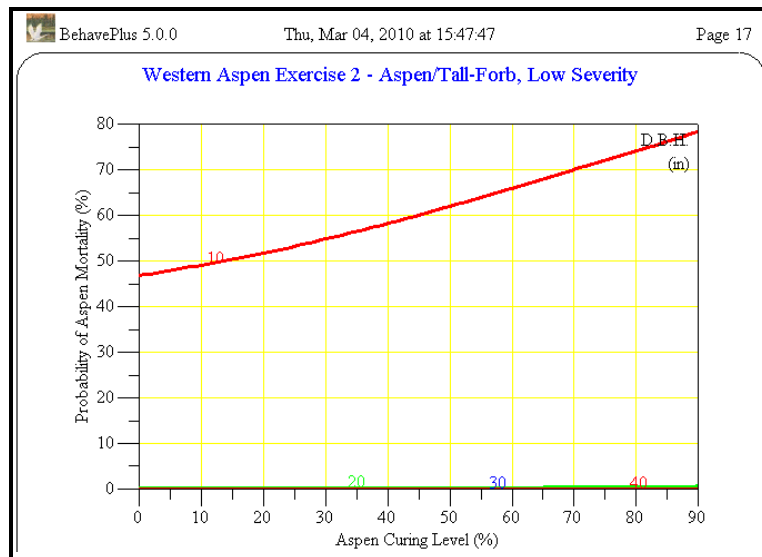
Fire

Aspen Fire Severity ➤ Low

You may wish to examine the tables of fire behavior and fuel outputs. Confirm that D.B.H. only plays a role as an input to the Probability of Aspen Mortality. To save space, this lesson will skip to the Fire Characteristics Chart to examine the fire behavior of the Aspen/Tall Forb Fuel Model.



Fire behavior for this Aspen Fuel Model is also relatively benign, but aspen mortality is high for trees with smaller D.B.H. (10-inch).



Repeat this exercise for the remaining three Aspen Fuel Models, leaving all other inputs unchanged. Examine your results. Which fuel model exhibits the greatest fire behavior? The least fire behavior? Which fuel model has the greatest mortality? The least mortality?


The Aspen/Low-Forb model, under the same environmental conditions as the other fuel models, produces even lower values of Flame Length, Surface Rate of Spread, and Heat per Unit Area. Mortality, even for the 10-inch D.B.H. class stays below 40%.

3. The 10-inch D.B.H. aspen are vulnerable to high mortality as shown in our previous exercises. This exercise will explore the effect of wind on fire behavior outputs and aspen mortality in the five aspen fuel models. Curing level will represent late summer or early autumn conditions (“50%”) and dead fuel moisture values will be set at fairly high representing conditions (1-h at “12%” and 10-h at “14%”) after some rain or with shorter days and longer periods of increased relative humidity at night. Live herbaceous is “150%”, live woody at “75%.” Midflame Wind Speed will range from “0” through “20” at “5” mi/h increments. There is no (“0%”) slope. Aspen Fire Severity is “Low.”


The following image shows the completed Worksheet for the “Aspen/shrub” fuel model, with all aspen outputs selected.


BehavePlus 5.0.0 Thu, Mar 04, 2010 at 16:51:35 Page 1

Inputs: SURFACE


Description  Western Aspen Exercise 3 - Aspen/Shrub

Fuel/Vegetation, Surface/Understory


Aspen Fuel Model  Aspen/shrub


Aspen Curing Level %  50


Fuel/Vegetation, Overstory


D.B.H. in  10


Fuel Moisture

1-h Moisture %  12


10-h Moisture %  14

100-h Moisture %  150


Live Herbaceous Moisture %  150

Live Woody Moisture %  75


Weather

Midflame Wind Speed (upslope) mi/h  0, 5, 10, 15, 20

Terrain

Slope Steepness %  0

Fire

Aspen Fire Severity  Low

Run Option Notes

A special case fuel model is used: western aspen
(Brown and Simmerman 1986) [SURFACE].

Maximum reliable effective wind speed limit is NOT imposed [SURFACE].

Calculations are only for the direction of maximum spread [SURFACE].

Fireline intensity, flame length, and spread distance are always
for the direction of the spread calculations [SURFACE].

Wind is blowing upslope [SURFACE].

Output Variables

Surface Rate of Spread (maximum) (ch/h) [SURFACE]

Heat per Unit Area (Btu/ft²) [SURFACE]

Fireline Intensity (Btu/ft/s) [SURFACE]

Flame Length (ft) [SURFACE]

Reaction Intensity (Btu/ft²/min) [SURFACE]

(continued on next page)

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 16:51:35 Page 2

Input Worksheet (continued)

Fire Characteristics Chart [SURFACE]

1-h Fuel Load (ton/ac) [SURFACE]

Live Herbaceous Fuel Load (ton/ac) [SURFACE]

Live Woody Fuel Load (ton/ac) [SURFACE]

1-h SA/V (ft²/ft³) [SURFACE]

Live Woody SA/V (ft²/ft³) [SURFACE]

Probability of Aspen Mortality (%) [SURFACE]

Notes

Aspen/shrub model, range of wind speeds, low severity

A subset of the outputs follow.

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 16:51:35 Page

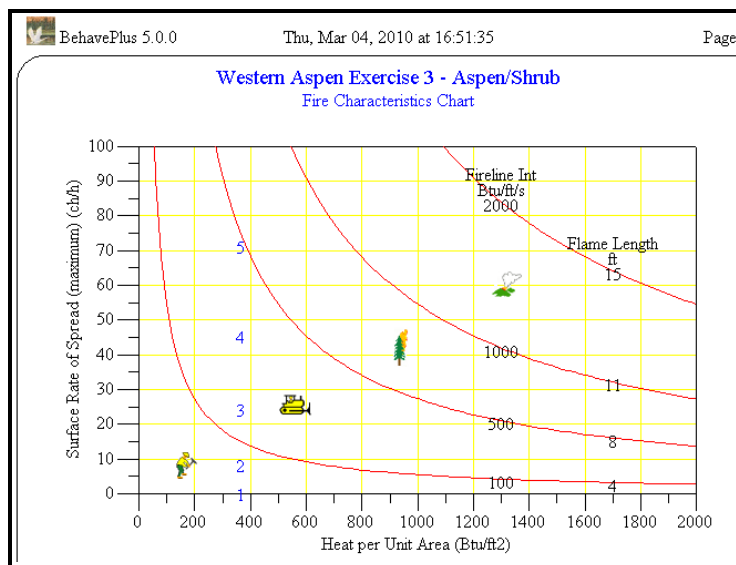
Western Aspen Exercise 3 - Aspen/Shrub

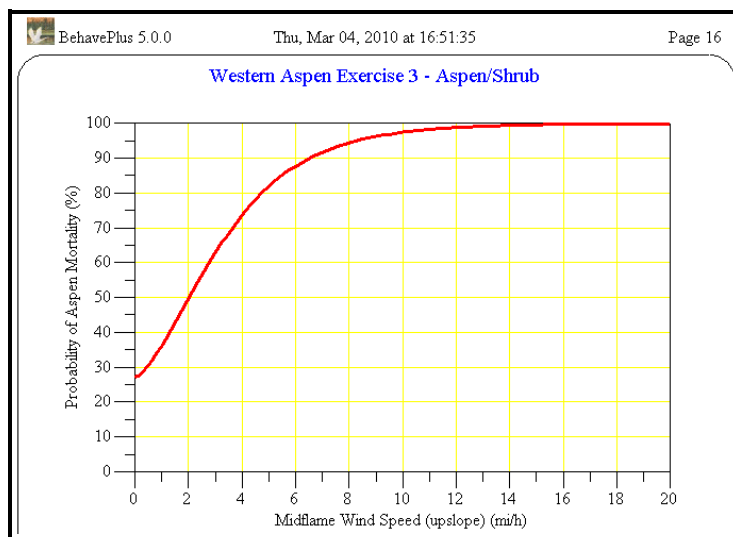
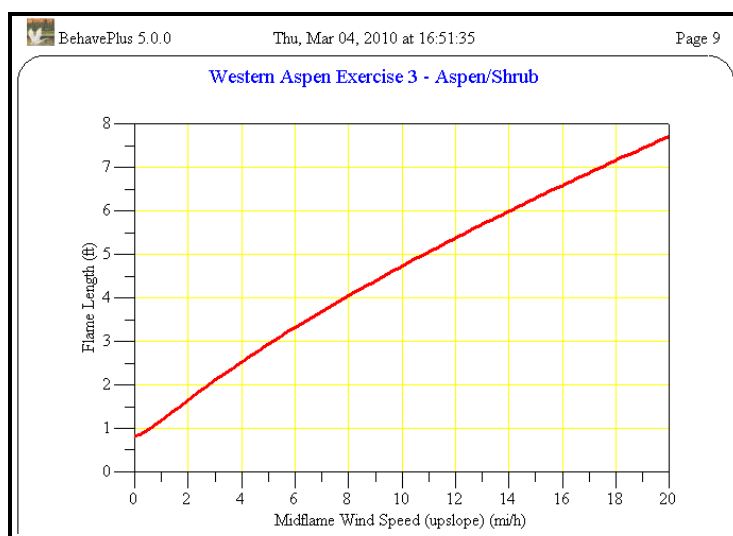
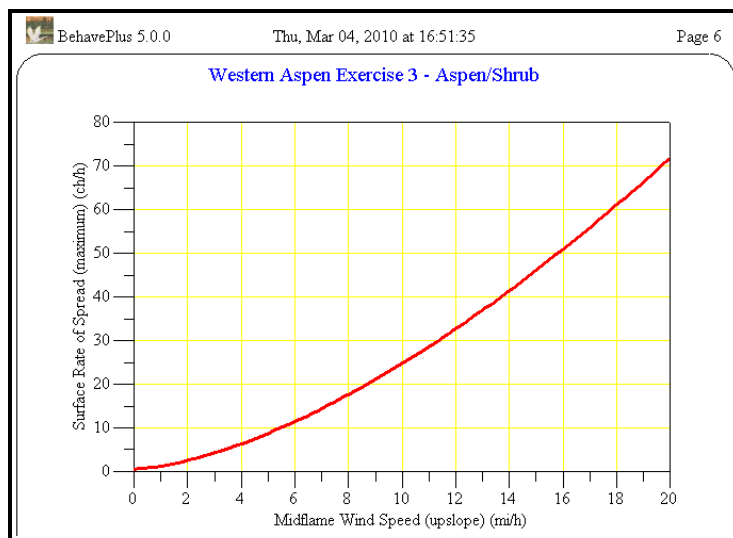
Midflame	ROS	Heat per	Fireline	Flame	Reaction	1-h
Wind Speed	(max)	Unit Area	Intensity	Length	Intensity	Load
mi/h	ch/h	Btu/ft ²	Btu/ft/s	ft	Btu/ft ² /min	ton/ac
0	0.6	367	4	0.8	1974	1.056
5	8.8	367	59	2.9	1974	1.056
10	24.7	367	166	4.7	1974	1.056
15	46.1	367	309	6.3	1974	1.056
20	71.8	367	482	7.7	1974	1.056

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 16:51:35 Page

Western Aspen Exercise 3 - Aspen/Shrub

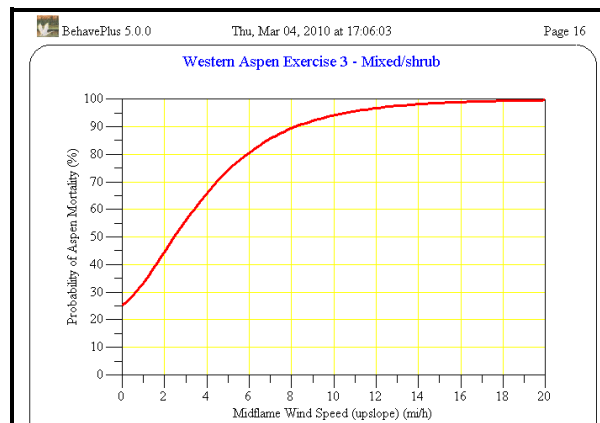
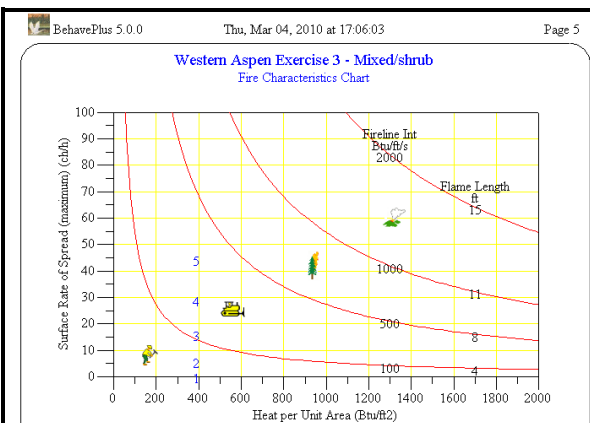
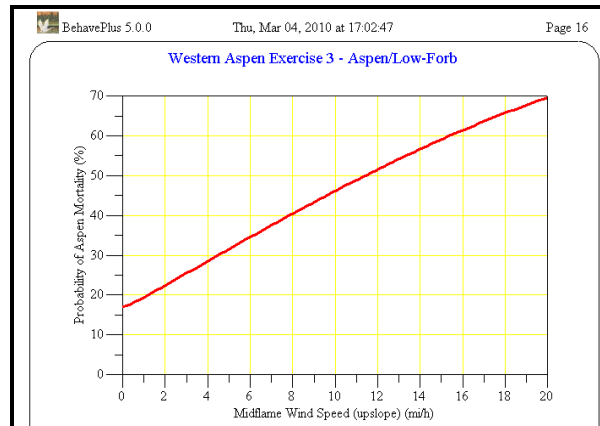
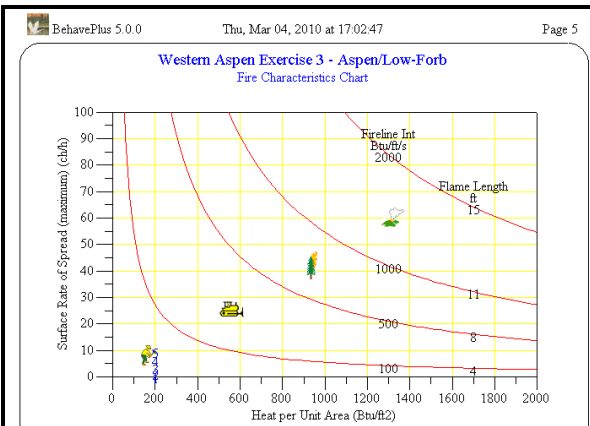
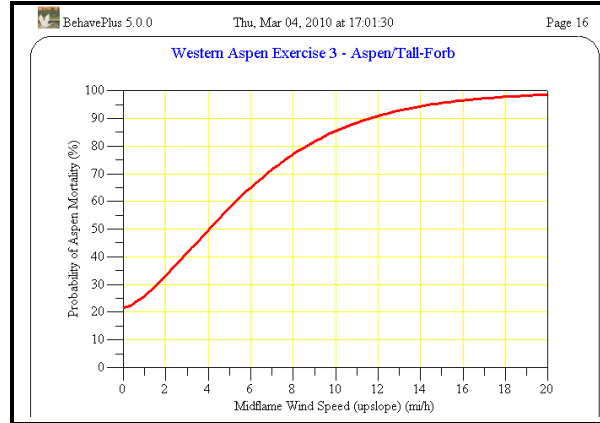
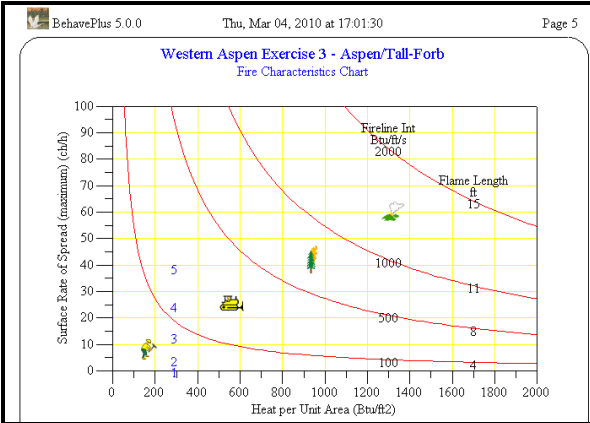
Midflame	Herb	Woody	1-h	Woody	Aspen
Wind Speed	Load	Load	SA/V	SA/V	Mortality
mi/h	ton/ac	ton/ac	ft ² /ft ³	ft ² /ft ³	%
0	0.167	0.333	1910	2310	27
5	0.167	0.333	1910	2310	82
10	0.167	0.333	1910	2310	97
15	0.167	0.333	1910	2310	100
20	0.167	0.333	1910	2310	100

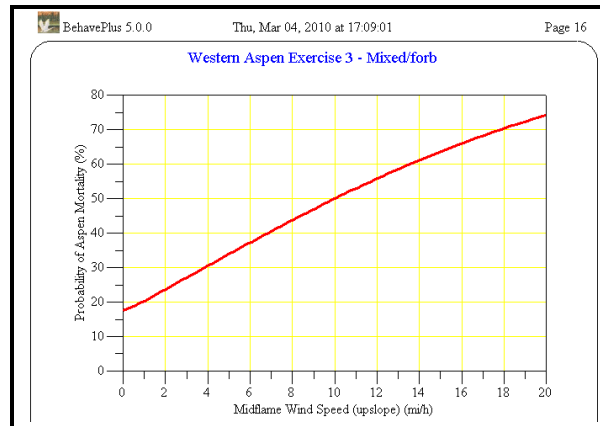
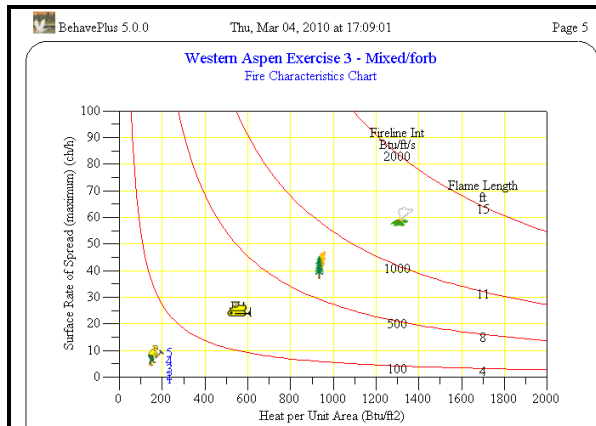




The Aspen Probability of Mortality rapidly increases with increasing Midflame Wind Speed. Recall, Flame Length is one of the calculated inputs to the aspen mortality model.

Examine the other Aspen Fuel Models using the same inputs. For your comparison, we will display the Fire Characteristics Charts and mortality graphs for each model.





4. Just because I am curious (aren't you?), explore the outputs given a **Moderate⁺** fire using the aspen fuel model with the flashiest and most benign fire behavior outputs. All other inputs remain the same as for Exercise 3. What fire behavior outputs are and are not affected by the change in fire severity?

I chose "Aspen/shrub" (flashiest) and "Aspen/low-forb" (most benign).

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 17:13:58 Page 3

Western Aspen Exercise 4 - Aspen/shrub

Midflame Wind Speed m/h	ROS (max) ch/h	Heat per Unit Area Btu/ft2	Fireline Intensity Btu/ft/s	Flame Length ft	Reaction Intensity Btu/ft2/min	1-h Load ton/ac
0	0.6	367	4	0.8	1974	1.056
5	8.8	367	59	2.9	1974	1.056
10	24.7	367	166	4.7	1974	1.056
15	46.1	367	309	6.3	1974	1.056
20	71.8	367	482	7.7	1974	1.056

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 17:13:58 Page 4

Western Aspen Exercise 4 - Aspen/shrub

< Midflame < Wind Speed < m/h	Herb Load ton/ac	Woody Load ton/ac	1-h SA/V ft2/ft3	Woody SA/V ft2/ft3	Aspen Mortality %
0	0.167	0.333	1910	2310	84
5	0.167	0.333	1910	2310	100
10	0.167	0.333	1910	2310	100
15	0.167	0.333	1910	2310	100
20	0.167	0.333	1910	2310	100

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 17:15:47 Page 3

Western Aspen Exercise 4 - Aspen/Low-Forb

Midflame	ROS	Heat per	Fireline	Flame	Reaction	1-h
Wind Speed	(max)	Unit Area	Intensity	Length	Intensity	Load
mi/h	ch/h	Btu/ft ²	Btu/ft/s	ft	Btu/ft ² /min	ton/ac
0	0.1	204	1	0.3	889	0.671
5	1.6	204	6	1.0	889	0.671
10	3.8	204	14	1.5	889	0.671
15	6.7	204	25	2.0	889	0.671
20	9.9	204	37	2.4	889	0.671

BehavePlus 5.0.0 Thu, Mar 04, 2010 at 17:15:47 Page 4

Western Aspen Exercise 4 - Aspen/Low-Forb

< Midflame	Herb	Woody	1-h	Woody	Aspen
< Wind Speed	Load	Load	SA/V	SA/V	Mortality
< mi/h	ton/ac	ton/ac	ft ² /ft ³	ft ² /ft ³	%
0	0.075	0.000	1620	2440	65
5	0.075	0.000	1620	2440	88
10	0.075	0.000	1620	2440	95
15	0.075	0.000	1620	2440	98
20	0.075	0.000	1620	2440	99

Looking at the tables with either Low or Moderate+ severity (as above) is one way of looking at the results (comparing your answers from Exercises 3 and 4). Running BehavePlus with a range of Midflame Wind Speed and the two severity options is another way to determine which fire behavior variables are affected by severity. As shown below, only Aspen Probability of Mortality is affected by fire severity.

